Proceedings of the American Academy of Arts and Sciences

Vol. 75, No. 4, P. 95–107—May, 1943

CHAO HSÜEH-MIN'S OUTLINE OF PYROTECHNICS A CONTRIBUTION TO THE HISTORY OF FIREWORKS

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The history of fireworks is very obscure. It is generally believed that pyrotechnic mixtures of saltpeter with sulfur and charcoal, or with other materials, were invented in China at an early time and were used for entertainment, for purposes of magic as in the exorcising of demons, and later in the military art. A knowledge of these mixtures presumably found its way to Europe over the trade routes to Byzantium. The celebrated *Liber ignium ad comburendos hostes* of Marcus Graecus, which was probably written in Greek in the eighth century, describes Greek fire and other incendiaries as well as black powder and the use of the latter material in firecrackers and in primitive rockets without sticks. The writings of Roger Bacon in the thirteenth century, which contain what is supposed to be the earliest reference to black powder in Latin Europe, make mention of the fact that toy firecrackers were already in use by the children of the time. Modern improvements, the use of chlorate and perchlorate in colored fire compositions, strontium and barium salts to color the flame, and magnesium and aluminum to impart brilliancy, have come in since 1800; they are recent enough to be dated, and certain of them may probably be set down as the inventions of particular men. But it is not known who invented the Roman candle, the rocket, the flying pigeon, the catherine wheel and the saxon, and it is not known when or by whom such familiar and much-used substances as arsenic sulfide, antimony sulfide, verdigris, calomel, and iron and steel filings were introduced into pyrotechny.

The literature of fireworks is meager. Contemporary books in European languages are few and far between, and are issued in such small editions that they quickly become out of print. Books before 1800 are rare without exception, but they are especially valuable to students of the history of pyrotechnics for the reason that they antedate modern improvements and indicate the state of the art during a time when it was advancing with exceeding slowness. Fireworks in the eighteenth century were but little advanced over those of the seventeenth century. The latter showed considerable improvement over those of Marcus Graecus in the mechanical devices in which they were applied but very little in the materials from which the compositions were made. During seven or eight centuries the addition of each new substance to the list of the pyrotechnist's materials must have represented a real achievement.

The Chinese text which is under discussion in the present paper is the only Chinese text on civil pyrotechnics[1] which we have been able to find. It represents an art which is more highly developed in some respects than the pyrotechnic art of eighteenth century Europe, an art which apparently grew up entirely independently in China. It lacks certain things which were common in European treatises, and it mentions certain things which would certainly have been copied in Europe if they had been known. It appears to be wholly Chinese.

The *Huo-hsi lüeh* 火戲略 (Outline of Pyrotechnics) by *Chao Hsüeh-min* 趙學敏 is printed in the collection, 昭代叢書[2] where it has a postscript by *Yang Fu-chi* 楊復吉 which is dated 1753. It was therefore in existence at that date. A short biography of its author is included in the *Hang-chou fu chih* 杭州府志 (Record of the District of *Hang-chou*) 150.16 b–17a (1923 ed.), and considerable information about him and about his father, his brother, and his own work in medicine is given in his two prefaces to his famous Supplement 拾遺 to the *materia medica*, *Pên-ts'ao kang-mu* 本草綱目.[3] The prefaces are dated 1770 and 1765, but they contain no reference to their author's age at the time when they were written.

Chao Hsüeh-min, whose *tzŭ* was *Shu-hsien* 恕軒,

[1] Dr. A. W. Hummel, Chief of the Division of Orientalia, Library of Congress, has kindly directed our attention to two earlier texts on military pyrotechnics, and has made it possible for us to procure microfilms of them. We hope to report upon these shortly.

[2] Volume 170 of the edition in the Library of Congress.

[3] We wish to make grateful acknowledgment to Dr. A. W. Hummel for giving us references to this material, to Dr. *Ch'iu K'ai-ming* 裘開明 for finding it for us in the Library of the Harvard-Yenching Institute, to the Harvard-Yenching Institute for the use of its text of the *Huo-hsi lüeh* and for the use of the Chinese type which has been employed in the present printing, and to Professor James R. Ware of Harvard University for reading the manuscript and for valuable criticism and suggestions.

was a native of *Ch'ien-t'ang* 錢塘 in *Hang-chou* (Chehkiang Province). He lived during the *Ch'ien-lung* 乾隆 era (1736–1796). His father was Salt Commissioner of *Hsia-sha* 下砂 county. The story goes that his father longed for sons. One day, when he was in *Ching-k'ou* 京口, he met a stranger who said to him, "According to your physiognomy, you will not have any successor, but, if you do beneficial relief work, you may get sons." There was an ocean flood which caused the death of hundreds of thousands of people. He did his best to rescue them and to bury the dead. In the autumn a plague followed, and he again contributed his salary to help, to procure medicines and the services of physicians. Thousands of lives were saved in consequence. He also suggested to the government a plan for the building of a dike. The officers in charge allowed the plan to be heard by the Emperor, and it was approved. Before any action was taken, many fields were badly damaged by the ocean tides, and seven counties, *Hsia-sha*, *Shih-yen* 石堰, *Ch'uan-shan* 穿山, *Ming-hao* 鳴鶴, *Lung-t'ou* 龍頭, etc., were inundated. He managed however to build the dike himself, and when it was finished he named it *Li-chi* 利濟 (Beneficial Relief). In the autumn of that year the ocean tides came again, but they were stopped by the dike and no damage was done. Later he was moved from this post to hold office in *Yu-ch'i* 尤溪. And so it came about that his sons, *Hsüeh-min* and *Ch'iai* 楷 were born, and were given the baby names of *Li* 利 (Beneficial) and *Chi* 濟 (Relief). When the father retired from his post, he also gave his hall the same name of *Li-chi*.

The father wished one of his sons to study Confucius and the other to study medicine. *Ch'iai*, the younger, studied the teachings of Confucius but also studied the canons on typhoid and on fevers. In his leisure time he was taught "to draw the copper man diagrams" [study acupuncture] for fun. From spring to winter the brothers studied in the Nourishing Essence Garden 養素園, which was fifty *mou* 畝 of land (more than six acres) devoted to the cultivation of medicinal grasses. *Hsüeh-min* encouraged his brother to specialize in medicine (*Ch'i-Huang* 岐黃) in accordance with the wish of his father. Although *Ch'iai* did not have confidence enough in himself to practice medicine publicly, relatives and friends who called upon him for diagnosis and who took his medicine were all cured of their diseases. He wrote a work entitled "Mirror of Herbs" 百草鏡 in 8 *chüan* 卷, and another on "Saving Lives from the Ocean of Sorrows" 救生苦海 in 100 *chüan*.

Chao Hsüeh-min was a great reader. It was his custom to continue his reading into the night. He says that he liked especially to read about the stars and the calendar, about medical subjects, and about divination and alchemy. When he found anything which interested him, he was so pleased that he forgot fatigue; he copied it or summarized it, and filed the material in packages. In this way he accumulated several thousand *chüan*. In the first of the prefaces which accompany his Supplement 拾遺 to the *Pên-ts'ao kang-mu*, he says that he almost became tired of this kind of work, and that once, when he had the time available to look them over, he picked out those which he thought to be useless and threw them in the furnace. He wrote *Li-chi shih-êrh chung* 利濟十二種 (Twelve Books from Li-chi Hall), as follows—

1. The Best Works of the Medical World 醫林集腋, 16 *chüan*,
2. Transmitted Trustworthy Formulas from the Nourishing Essence Garden 養素園傳信方, 6 *chüan*,
3. Proofs of Exorcism 祝由錄驗, 4 *chüan*,
4. Collections 集 under the Names of *Nang* and *Lu* 囊露 (herbs), 4 *chüan*,
5. Observations 話 on the *Pên-ts'ao*, 32 *chüan*,
6. A Gathering of Selected Formulas (of the author and others) 串雅, 8 *chüan*,
7. A Report on the Short Names of Certain Herbs 花藥小名錄, 4 *chüan*,
8. The Secrets of Rising and Sinking 升降祕要, 2 *chüan*,
9. Leisure Readings on the Maintenance of the Health 攝生閒覽, 4 *chüan*,
10. Explanations of the Properties of Medicines 藥性元解, 4 *chüan*,
11. References to Strange Medicines 奇藥備考, 6 *chüan*, and
12. Supplement to *Pên-ts'ao kang-mu*, 10 *chüan*.

The twelve titles were published in the book catalogue of the *Pao* 鮑 family, and the manuscripts were circulated. At the end of the *Chia-ch'ing* 嘉慶 era (1796–1821) only the manuscripts of Nos. 6 and 12 survived, and these texts were preserved in the *Hang i lien pao* 杭醫連寶 (The United Treasure of Hangchow Medical Doctors). *Chang Ying-ch'ang* 張應昌 reorganized the material in these two texts, corrected the mistakes, and edited and published them in the middle of the *T'ung-chih* 同治 era (1862–1875). The other ten texts have been lost. The manuscripts of the family are said to have been destroyed about 1860 in the Taiping Rebellion.

Of the two prefaces by *Chao Hsüeh-min* which now accompany his Supplement to the *Pên-ts'ao*

kang-mu, the second is properly a preface to the Supplement and describes his reasons for writing it. The first is really a preface to the whole collection of Twelve Books on Beneficial Relief, and tells something of the circumstances surrounding the writing of each of the treatises. The author says—

"Of the Twelve Books which I wrote, the manuscripts of two, namely, of the 'Proofs of Exorcism,' and the 'Gathering of Selected Formulas,' were set aside last year to be put on the fire, but the manuscripts were saved by the children. The treatise, 'The Best Works of the Medical World,' was completed a year ago. Once I happened to have a chance to read the books in the library of my neighbor, *Huang Fan-wêng* 黃帆翁, in which the collection of books on medicine amounted to more than ten thousand *chüan*, and I compared them with my old collection of confidential papers of the Kiangsu and Fukien authors. I selected from them the formulas which had always proved effective to form a treatise entitled 'Best Works.' It was my experience that the selection was not easy. Some of my relatives and friends happened to test the formulas, and told me of improvements. The treatise was then revised, and enlarged from year to year, and its name was changed to 'Transmitted Trustworthy Formulas.'

"In the spring of the year *i-hai* 乙亥 (1755), *Wang Tzŭ-shih* 汪子師 of Hunan Province paid me a visit and made a short stay in my home. I saw on his desk a volume on exorcism, the formulas of which he was testing. I then borrowed the book and copied it myself, and later secured other manuscripts, those of the *Chang* 張 family, of the *Wan* 萬 family, and of the *Hsieh* 薛 family. I tested some of the formulas from them, removed the false ones, saved the effective ones, and wrote the book, 'Proofs of Exorcism.'

"I was addicted to the reading of books. The daytime was not enough for my study, and I continued it by the burning of fat. I disliked to yawn in the study hall, and so I built a box for the lamp and brought it into the mosquito net in order to carry on my reading at night. After some time the soot from the lamp blackened the beautiful net. In the year *ping-tzŭ* 丙子 (1756) I had eye disease. The disease was so serious that I almost became blind; after six months of sightlessness it was finally cured. For this reason I wrote another book entitled 'Collections under the Names of *Nang* and *Lu*.'[4] . . .

"Someday if I can devote my time to studying the canons on the impulse of the blood, on typhoid, on fever, etc., and can organize the material into treatises, I shall write ten more books. These, together with the two books written by my brother, I shall put into a 'Later Twelve Books from Li-Chi Hall.' The year *kêng-yin* 庚寅 (1770), the second month of spring, the sixth day of the month. *Chao Hsüeh-min, Shu-hsien.*"

The *Huo-hsi lüeh* (Outline of Pyrotechnics) is probably one of the earlier works of *Chao Hsüeh-min*, for the note of commendation appended to it by a reader is dated 1753, more than a decade earlier than the dates (1765 and 1770) which *Chao Hsüeh-min* has himself given his own prefaces to the Supplement to the *Pên-ts'ao kang-mu*. The treatise appears to be one of those collections of notes, or summaries of readings, of which *Chao* says that he accumulated several thousand *chüan*. It shows an acquaintance with the materials of the pyrotechnist, and with their properties and uses, and leads one to believe that its author had handled them himself. It appears to consist essentially of the notes and observations of a skilful worker in the art, addressed to one who is already familiar with the principles. It omits many details. It does not, for example, tell how saltpeter is prepared, but it indicates a true understanding of the unfavorable effect of sea salt which may be present in it as an impurity. It shows an interst in the theoretical basis or explanation of the observed facts. It contains no mention of antimony sulfide which was widely used in eighteenth century European pyrotechnics, and conversely it refers to materials and techniques which had not yet been applied in European practice. Many of its points of interest are discussed in the notes which follow the Translation and Abstract and which are numbered with the same numbers as the paragraphs of the Translation and Abstract to which they refer.

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[4] *Nang* and *Lu* are herbs which are used in the treatment of eye disease.

TRANSLATION AND ABSTRACT

HUO HSI LÜEH 火戲略 *AN OUTLINE OF PYROTECHNICS*

By Chao Hsüeh-min 趙學敏

Extraction of Saltpeter

1. [1a–2a] *Hsiao* 硝 (saltpeter) is produced in salty places (salt marshes). The districts in *Ch'ing-yang* 慶陽 (in Kansu) and in *Ho-pei* 河北 (in Honan Province) and the interior of *Shu* 蜀 (*Ssŭ-ch'uan* 四川 Province) have an abundance of this substance. During the autumn and wintertime the ground is covered with a white material which is swept up with a broom and refined by boiling (its solutions), and *hsiao* is thus obtained. In *Ts'ui Fang's* 崔昉 *Wai-tan* 外丹 (exterior *tan*), and in the *Pên ts'ao* 本草 (Book of Medicines), it is called *yin shih* 陰石 (stone of *yin* 陰). In *Fu hung t'u* 伏汞圖 (Diagrams of Conquering Mercury) of *Hu-kang-tzŭ*, 狐剛子 it is also named *pei ti yüan chu* 北帝元珠 (the primary pearl of the Northern God).

2. *Hsiao* (saltpeter) gets its name, I suppose, from the fact that it is the essence of *T'ai yin* 太陰 (the Grand *yin*, synonym of the moon) and will fly away on meeting fire. At the extremity of *yin* 陰, *yang* 陽 begins to appear. *Hsiao* pertains to *li* 離 (a *kua* 卦, namely ☲, standing for *yin*), and has the property of being able to soften the five metals and to change the seventy-two stones into water.

3. The word *hsiao* means to dissolve (to vanish). It (*hsiao*) must be refined for use as an internal medicine. The same is true for use in making fireworks. It is thought that *hsiao* is formed by the influence of the ethereal essence of the salty sea, since it becomes wet in contact with a humid atmosphere. Dryness is essential for *huo yao* 火藥 (fire powder, black powder). If unpurified [1b] *hsiao* is mistakenly used to make the powder, the charcoal of the powder will become moist very easily during humid weather. The iron filings (in the powder) will be surely rusted from the effect of the *lu ch'i* 鹵氣 (ethereal essence of salt) caused by the wet charcoal. It is unlikely that such a powder can produce any good result in *hua p'ao* 花砲 (flower cannon, flower rocket). Consequently, the *hsiao* must be purified to get rid of the *lu ch'i* (ethereal essence of salt) before it is compounded in the fire-powder.

4. For the method employed in the preparation: *hsiao* is put in a large iron kettle, covered with clear water until the water rises one or two *ts'un* 寸 (inches) above the *hsiao*, two *liang* 兩 (ounces) of water glue (glue solution) is added and the contents is boiled for a period of two incenses (the time needed for burning consecutively two pieces of incense). When the liquor boils, foam may form and, in such case, is skimmed off. Remove from the fire and let the liquor stand until clarified. On the next day the supernatant liquor is decanted off and is replaced by fresh water. About three or five white turnips are then added and the contents boiled for another two incenses. Again, remove from the fire, remove the white turnips, and let the liquor clarify as before. Next morning, replace (the supernatant liquor) with fresh water, add new white turnips, and boil the whole again for two incenses. The *lu ch'i* (ethereal essence of salt) is completely removed by such treatment. The *hsiao* is taken out and dried in the sun light.

5. If one wishes to prepare roasted *hsiao*, good *shao chiu* 燒酒 (distilled spirit, samshoo) is added slowly in the kettle to the purified *hsiao* mentioned above, and the contents is roasted to dryness to get the product. Another method for manufacturing *hsiao* is given in *Shui shu pên fang* 水鼠本方 (Original Methods of Making Water-Mice)*.

Preparation of Sulfur

6. [2a–b] *Huang* 黃 (yellow, sulfur) consists of the essence of pure *yang* 陽 of fire-stone. It is formed by condensing the *ch'i* 氣 (ethereal essence) of the sun. Workers in *Wai tan* (Exterior tan), call it *huang ya* 黃芽 (yellow sprout). It is probable that the essence of the sun (sulfur) acquires its body by the influence of wind and wood. The branches of wood (the element wood, sulfur) grow out sideways. Therefore, when they are mixed with charcoal, the flames shoot out sideways. Wood appears blue, therefore its flame (the flame of sulfur) is also blue).

7. Sulfur of light yellow color is named *k'un lun huang* 崑崙黃 (the yellow of *K'un-lun* 崑崙); that of red color, *shih t'ing chih* 石亭脂 (the fat of *Shih-t'ing*, red sulfur); that of blue color, *tung chieh shih* 冬結石 (winter-frozen-stone); while that which is half white and half black is called *shên ching shih* 神驚石 (stone of shocking spirits). They are produced everywhere, in the East, the West, the South, and the North. The grade for making rocket powder must be of deep yellow color. If the bluish grey material is used, there will be a hazard of explosion due to its uncleanness. If one

* Water-mice are small fireworks intended for use under water.

wishes to treat it with distilled spirit, do not roast it, but stir it and expose it for drying in the sunlight. If it catches fire on roasting with other ingredients, then by using your mouth spray vinegar onto it to stop the fire. If you wish [2b] to remove the odor, make a hollow chamber in a white turnip, fill the chamber with the pulverized sulfur, put the white turnip, into a heap of burning rice-hulls until it is cooked, and the odor is gone.

8. If you wish to change sulfur into a liquid, fill a bamboo cylinder with your sulfur, bury the cylinder in horse dung for one month and you will get the liquid sulfur. This liquid has the characteristic properties of turning the five metals black, of turning mercury red, of giving a purple color with magnetic stone, of making a disturbance with saltpeter, and of becoming quiet with pig fat. One should understand these properties and be able to utilize the sulfur well.

The Use of Charcoal

9. [2b–3b] Charcoal is the soul 魄 of fire. Fire resides in (the element) wood, and wood comes from (the element) water. Whenever wood dies, it turns black to show that it has returned to its original form. The properties of charcoal are to fly away and to give out light easily. It is used in accordance with its properties. The charcoal which is usually used for the making of powder is that from the extreme ends of fir branches. Other varieties are bamboo shoot charcoal which is violent and spreading, bamboo knot charcoal which is violent and powerful, bamboo root charcoal which is hard and side-bursting, calabash vine charcoal which is quick and side-running, bamboo leaf charcoal which gives a hissing sound, cocoanut [3a] shell charcoal which produces splashing noises, mellon skin charcoal which is quick and violent, eggplant charcoal which makes clear crackling sounds, horn charcoal which is permeable to flame, snake skin charcoal which gives flashing light, and grasshopper charcoal which possesses the property of flying away and running. The quick acting powders have the property of destroying and bursting. Charcoal from glutinous rice can be used to make bird-gun powder. Willow and fir charcoals are the lightest of all and can be used to make powders for *Shou hua* 手花 (hand flowers). *P'ao* 砲 (cannon) using ashes of hempstalk (in the powder) produce no noise. If the flinty skin of bamboo is used, plenty of smoke results. Other effects can be produced by applying your knowledge.

10. Charcoal must be prepared by burning (the raw material) until the last trace of smoke is driven off. It is then taken out and put into an earthenware jar which has a tight cover. After cooling it is pulverized to the finest degree for use in powder. This substance is much disposed to become moist, and so it must be burned (prepared) just before use. If too much of it has been made, the unused portion must be wrapped in a piece of paper and put into a jar containing (burnt) lime.

11. If the charcoal has been exposed to moist air, it will be unreliable in its effect upon the slowness and quickness of the finished powder, and also it will make the finished powder fail to burn out (produce) colors and flowers. Furthermore, the iron filings will not be completely melted (if used) with such a charcoal.

12. However, there is a wet method for making powder. For instance, in the preparation of *chu êrh yao* 珠兒藥 (bead powder), saltpeter is boiled with the charcoal and the (resulting) mass is pulverized when it is still moist. In the preparation of *hsüeh têng yao* 雪燈藥 (snow-lantern powder), [3b] camphor is boiled with charcoal and the product is also pulverized while in the moist conditions.

13. Another method is the cast-charcoal dry method. If you want it (the product) to appear as a silvery thread, (the material) is cast with lacquer and dried in the sunlight whereupon the properties of the powder are stabilized. If you want to change its color, you can drop it (into a kettle), roast it, and cast it. It depends upon yourself how much of the subject you can understand.

The Use of Iron Filings

14. [3b–4a] *Sha* 砂 (sand, powdered iron) consists of broken cast iron having grains as large as sand, and hence its name. Its old name was *t'ieh ê* 鉄蛾 (iron ants). It also has another name, *t'ieh hsieh* 鉄屑 (iron filings). Without it, *t'ung hua* 筒花 (cylinder sparks, cylinder flowers, fountains or gerbs) will no longer produce flowers (sparks).

15. It should be prepared at the time when it is used. It can not be stored for a long time because it has a tendency to rust. Once rusted, it will produce no more sparks. Old, broken, cast-iron kettles are usually employed (as the material) for making *sha*. The broken kettles are heated to a red heat in order to remove adhering grease and dirt. After cooling somewhat, they are pulverized in an iron mortar while they are still warm. The product is then sieved and separated into four grades. The fines are called upper *sha;* the coarser ones, medium *sha;* the still coarser grade, coarse *sha;* and the coarsest ones are called large *sha*. [4a] Besides these, there is another kind of *sha* which is known as

needle *sha;* it consists of drillings from the boring out of needles' eyes. After the *sha* is sieved, it is wrapped in paper and put in the lime jar to prevent it from rusting. Powdered iron is not to be touched with the hands, otherwise it becomes sparkless rust. Oil can also spoil powdered iron as it makes it melt into beads without producing sparks when burnt in powder (compositions). Powdered iron, when weighed, is to be handled with a copper spoon to avoid contact with the hands.

16. At the present time, powdered iron is all purchased from *Su-chou* 蘇州 (near Nanking). It should have a glistening lustre like that of tin.

The Match (Fuse)

17. [4a–b] Large match is called double wick match and small match single wick match. All kinds come from *Hui-chou* 徽州 (*An-hui* Province, lower Yangtze valley) (where they are manufactured) for use as open-lead igniters for *hua p'ao* (cannon). However, in fireworks there are still other igniters which are known as piped match. Matches are of two kinds, the slow ones and the quick ones. Quick matches are made with charcoal of calabash, the slow one with charcoal of willow or fir. *T'ao hua* 桃花 (peach flower) paper is used as the wrapping paper and should be treated beforehand with a solution of saltpeter (and dried) in the summer time. [4b] The powder is wrapped in by twisting the paper around it, and burns readily through a crimp.

18. Matches are packed in bundles of 500 pieces each with the two ends of the bundle tied by paper threads. They are stored in a lime jar for use at the time needed.

19. The powder for matches should be loaded on the paper with a match-spoon in order to get it even. The match-spoon is made from a piece of bamboo by cutting the bamboo to a size as small as a scallion leaf and to a length of about one foot in a thin (spoon) shape. When powder is loaded on paper with this spoon, there will be an even distribution of the powder and match of uniform size will thus result.

Use of Piped Match (Abstract)

20. [4b–5b] Piped match is a match enclosed in a paper tube, the tube being about the size of a wheat straw and fireproofed with alum. In a display of fireworks, piped match is used for connecting the different pieces in order to prevent all of the matches, which cross each other, from burning together at one time, so that the display can be shown in systematic order. Furthermore, the fire of the match is enclosed within the tube and is not visible. After the matches have burned, hundreds of flowers of fire appear suddenly, and the display is made much more amusing. The ends of the match are not piped, with the result that the tube, after the match has burned, finds no support for itself and thus drops away.

Treatment of Papers (Abstract)

21. [5b–6b] There are four kinds of papers used in making fireworks, fire-proof paper, inflammable paper, paper for a sharp crackling explosion, and paper for strength. Fire-proof paper is used in making the inner cylinders of fireworks, and is itself made by treating paper with alum solutions. In wrapping fuses, the paper must be inflammable; this result is secured by soaking it in saltpeter solution. For firecrackers the paper must be readily torn into small pieces by the explosion to produce loud, cracking reports with small fragments of paper filling the air. Bamboo or mulberry-bark paper will be suitable for this purpose. For a certain kind of flower cylinder (fountain), the outer layer of the cylinder must be made of strong paper to prevent the bursting of the cylinder, and for this purpose a layer of thick paper or *yüan-shu* 元書 paper is usually used.

22. [6a–8] Dyed paper must not be used in fireworks, because the color is likely to be destroyed by the powder. If color must be applied, the pigments which are used for ordinary painting will produce satisfactory results and will not be changed by contact with the sulfur fumes.

The Containers

23. [6b–7a] Containers are of three different sorts, namely, the clay cylinder, the paper cylinder, and the iron cylinder. For *p'ao* (cannon, firecrackers), only the first two are in use while all of the three are employed in flower cylinders (fountains). The mouth and the bottom of a cannon cylinder are equal in size, but in a fountain cylinder the mouth is small and the bottom is large forming a horn-shaped (or conical) space in between. (The conical container) will direct the force of the powder upward without being itself burst.

24. To test fountain powders there is a simple method for making the container. A small bamboo cylinder is cut off so that one of its ends retains the knot and the other is left open. The powder is packed into the cylinder until it is almost full. The open end is then blocked tightly with a choke of ashes wrapped in paper. [7a] A hole is made through the knot of the other end for inserting a fuse. This method obviously saves the laborous effort of mak-

ing a paper container. However, before packing in the powder, the cylinder must be packed with paper to make an inner horn-shaped (or conical) cavity with the tip (apex) against the knot. This removes the trouble of cracking or side-bursting. If a horn-shape cavity is made in a piece of dry clay and the clay is used (in the place of the paper) for packing the bamboo cylinder, the result will be the same.

The Compounding

25. [7a–8b] The most essential materials used in the compounding (of the powder) are the saltpeter, sulfur, and charcoal which have been discussed in detail previously. Others are auxiliary substances. However, one has to know the art of compounding. For instance, if *hsiung huang* 雄黃 (male yellow, realgar) or *shih huang* 石黃 (stone yellow, orpiment) is used, (the mineral) must be first stirred with *shao chiu* (distilled spirit) and dried in the sunlight. It will give a yellow smoke. If it is used together with saltpeter, the smoke will be very intense with a yellow light which will not be overshadowed by the light of the burning powder. If sulfur, which has an odor, is employed, it must be roasted with vinegar beforehand in order [7b] to remove the odor. By being admixed with *tsao chio kao* 皁角膏 (a fat from the pods of *gleditschia sinensis*), the powder acquires slowness. By being mixed with *fu jung chih* 芙蓉汁 (the juice of lotus flowers), the powder becomes quick acting. Shreds of cotton give a violet light; *t'ung ch'ing* 銅青 (copper green, verdigris, basic acetate of copper) produces a green light; *yin chu* 銀硃 (vermilion, cinnabar), a red light (smoke?); *ch'ien fên* 鉛粉 (lead powder, white lead, carbonate of lead), a white light (smoke?); *hsiung ching* 雄精 (realgar), a yellow light (smoke?); and *sung mei* 松煤 (pine soot), a black light (smoke?). The above contain the five colors of light (smoke?).

26. *Shih huang* 石黃 (orpiment) produces a yellow smoke; *ch'ing tai* 青黛 (lapis lazuli) a green smoke; *chu sha* 硃砂 (cinnabar) a red smoke; *ni fên* 膩粉 (greasy powder, calomel) a white smoke; and *li ch'ing* 瀝青 (pitch, resin) a black smoke. The addition of gold or silver foil makes a light similar to that of gold fragments. The addition of tin foil makes a light resembling that of broken red clouds. Sulfur alone makes it (the light) blue, while the addition of *tan fan* 膽礬 (bluestone, blue vitriol, copper sulfate) makes the light still stronger. Saltpeter alone renders the light violet. *P'i shih* 砒石 (white arsenic, arsenious acid) produces a still longer light (flame). *Shih nao yu* 石腦油 (rock oil, bitumen, asphalt), *chang nao* 樟腦 (camphor), and *ti sou* 地溲 (earth-extract) all can produce fire from water (liquid). The thorns of *gleditschia sinensis*, spring-willow-branches, bamboo shoots etc., all are able to produce something else in the fire. The presence of impurities in the root (the powder) is due to the incomplete extraction of the saltpeter. The feebleness of the flowers (sparks) is caused by the use of unfresh (deteriorated) iron filings.

27. If one wishes the powder to produce fruits, the spraying of water should be so plentiful as to be comparable to that of spring time. If you want the light to be controllable, (the powder) should be stirred with a bath of plums. Earthworm powder and snake skin are used according to their properties. [8a] Boiling in a solution and drying in the sunlight will bring out the efficacy. The persons who are able to do the job will not be limited by a single rule. The followers (students) should be able to derive everything from the above (discussion).

28. The proportions (quantities) must be accurate and the mixing must be thorough. Iron filings are of coarse and fine grades. (The addition of) charcoal has its own order. When the roasting method is used, the ingredients must be roasted separately. If the wet method should be chosen, the procedures would not be the same. The crushing and grinding apparatus should be in good condition and efficient. During the sieving, precautions must be taken with respect to wind and fire. Follow these rules and you will have over one-half of your thought (more than half of the expected results).

The Roasting of Powder

29. [8a–b] In making powder there is an excellent method of combining the advantages of water and fire. For example, *ch'iang yao* 鎗藥 (gunpowder) is made by boiling saltpeter and sulfur with water, roasting (the product) with charcoal and stirring to form the beads. *Huo chiu* 火酒 (fire spirit, alcohol) is sometimes used in the roasting. According to *Shui shu fang* 水鼠方 (Water and Mice Methods) of *Yün ch'i* 雲溪 (Cloud-spring) floating (upper) saltpeter, jumping saltpeter, and settled (bottom) saltpeter are recommended. In *Jên yüan fang* 仁源方 (Spring of Kindness Methods), alcoholic saltpeter is employed to make the five-color butterfly. A certain one roasts (the powder) with oil, lacquer, snake-blood, or juice of *fu jung* 芙蓉 (lotus flowers). Again, another roasts in the dry state or roasts with addition of other substances. Probably, the advantage of dry roasting is to absorb the power of fire for assisting the rising property (of the powder), while that of admixing with other substances is to make use of the power of

those substances to conform to the will of the *shên ming* 神明 (spirits).

30. There is no definite method. If you want to minimize the yellow flame, *tan fan* 胆礬 (blue-stone) will be mixed in. If you want to retain the light of saltpeter, (the powder) is to be boiled with rosin oil. If you want the powder whirling around, tails of grubs will be added during the roasting. If you want the powder to be spreading, earthworm blood will be added during the roasting. When silver foil is roasted for use in powder, ash of lotus leaves is to be added. When copper foil is roasted for use in powder, walnut ashes are to be incorporated. The reason is for controlling (the effect).

Miscellaneous Substances (Abstract)

31. [8b–10a] Common people know only that substances which are inflammable can be incorporated into fire powder. However, the non-inflammable materials, when used properly, produce wonderful results. This has been stated in the Books of *Tan*, that all substances can produce light. It is the substance of inflammable material and the spirit of non-inflammable which are effective. For instance, minerals such as *huang tan* 黃丹 (minium, red lead oxide), *mi t'o sêng* 蜜陀僧 (litharge) and *hei hsi hui* 黑錫灰 (black tin ash, lead), all are heavy and are able to suppress the power of the powder. *Ku ch'ing ch'ien* 古青錢 (old copper coins, old brass), *t'ieh hua fên* 鉄華粉 (acetate of iron) and silver rust are able to split fire to give flowers. *Lu kan shih* 爐甘石 (zinc bloom, zinc carbonate), *pu hui mu* 不灰木 (non-ashing wood, asbestos) and *shih chih kao* 石脂膏 (stone fat, siliceous clay) can be used to treat paper and to separate fire. *Ch'ing fên* 輕粉 (calomel), *chung ju* 鍾乳 (stalacitites, chiefly calcite), and *shih t'an* 石炭 (graphite) are able in certain cases to produce particular effects. *Yü shih* 礜石 (arsenolite, white arsenical ore), *huang fan* 黃礬 (yellow-colored alum), and *lei mo* 雷墨 (meteorites) all are able to invert the light. *Nao sha* 硇砂 (sal ammoniac), *p'êng sha* 蓬砂 (borax), and salt assist saltpeter and sulfur in the powder to burn out.

32. As for vegetable materials, (the charcoal of) rush stalks can change a small fire into a large one. Rosin can concentrate spreading light into spot light. (Numerous other effects of various vegetables and animal materials are also mentioned).

The Use of Powders (Abstract)

33. [10a–11a] If you want the piece to fly, the addition of mice-powder is necessary. If you want it bright, moon-lantern-powder should be added. Powders for filling soft containers are usually fine and are not quick-acting. If quick-acting powder is used (in this case), the container will be shattered and your hand may be injured. The flowers of soft pieces must shoot out sidewise and open slantingly, otherwise the choke will be blasted out and random burning result from the straight-upward shooting. With a large proportion of saltpeter, the force of the powder is tremendous. With plenty of charcoal, the light of the powder becomes scattering. Powders rich in sulfur make loud sounds, while those rich in powdered iron give obscure (unclear) flowers. The shaking of the container (unevenness of firing) is caused by the formation of obstructions in the mouth. The formation of beads on top of the flowers is caused by the use of rusted iron filings.

The Coatings and Pastes

34. [11a–b] It is necessary to know the use of coatings and pastes, for, by means of these, results from the powder are made much more wonderful and changeable. They are comparable to the color designs of a painter and to the pattern designs of a textile-maker. If a powder does not have a coating or paste, it will not be able to trace out its flight, and the weak and intense colors are not to be distinguished. It will also fail to concentrate the light, and the wonders of the changes will not be magnificent. This subject, therefore, ought to be discussed.

35. Whenever the grains of a powder have no particular shapes, the grains are called beads. Those which have corners, are called prisms. They may have the shape of grain-awns, chelae, hair, the scars of the moon, a broken wall, a broken sword, fractured calcite, or a heap of hooks. They may contain eight corners, a trident, a conical shape, or a shape of a bowl-head.

36. Some of these grains are shaped (molded) with open fire, with greenish fire, with explosion-powder, or with ignition-powder. It has been stated that powders which have a shape, can put on clothes. Red clothes (coating) consists of *chu sha* 硃砂 (cinnabar); green coating, of sulfur; blue coatings, of *t'ung lü* 銅綠 (verdigris, green copper); white coating, of *ch'ien fên* 鉛粉 (lead powder, white lead); and coatings of other colors will be made up in a comparable manner.

37. Some people use a paste. For example, when cotton is coated with a sulfur paste, (and is used in the powder), the fire with purple-green balls will fly out. When tin foil treated with a saltpeter-sulfur paste is used, one can see the fire spitting out colored light (flames). If wick-grass is used in the powder, the paste-method must be applied. Some-

times powdered iron is also coated or pasted. When this is used in fountains, the flowers are much more deceptive and marvelous. Again, some one uses powder to coat upon the coat, a paste upon the coat, one side with coat while the other with paste, or coating and paste in the center. In another method, the grains of the powder are dressed (coated), made into shape, wrapped together, and coated again. This is called the seven-star coating. The method of using one layer of coating, then one layer of powder, and so on, layer after layer, is called case-coating. Sometimes, the pipe of a piped match is also coated or pasted. This kind of trick is not understood by those who have not specialized in the art.

The Packing in of the Powder (Abstract)

38. [12a–b] To save labor, the powder for fire-crackers is loaded into 300–500 small, colored cylinders at one time, all of the cylinders being made up into an hexagonal bundle with the openings facing upward, and the powder is then run in from a long spoon (funnel). In packing fountains, the powder, after loading, must be stirred to prevent the settling down of the powdered iron, and is not to be shaken, otherwise, the ingredients will be separated from each other with the charcoal on top, and the saltpeter and sulfur at the bottom. The powder for crackers must be packed loosely but the powder for fountains is pressed hard.

Auxiliary Shows (Special Pieces) (Abstract)

39. [12b–13b] The Hundred Sons, The Three Ranks, The First of All, Lucky Clouds, Butterflies, Rockets, Flowers of the Moon, Brick Flowers, The Nine Dragons, the Eight *Hsien* 仙 (immortals), etc., are auxiliary shows (special pieces). They may be fired singly or may make up a part of a play. They go up in the air, jump on the ground, and fly to the one side or dance on the other. These furnish motions in front of a stationary spectacle. Rockets are the eyes of fireworks, and are fired before the main display in order to quieten the audience.

40. There are some fireworks for display in the day time. They are called smoke-plays, and make use of smokes. They may be so constructed as to display colored buildings, towers, human beings, mountains, waters, and various spectacles. The auxiliary shows (special pieces) may be earth mice (ground mice), water mice, snow crackers, smoke crackers, incense lanterns, falling pearls, smoke horns, foggy orchids (orchids of mist or smoke), colored wheels, colored wings, etc., while colored rockets are used as the first fire. The flower shells are shells filled with powder for enlarging the shows and are to be reckoned as special pieces. Shells of fruits, nuts, fir cones, calabash, paper, clay, wood, etc., are also used.

Flexible Pieces (Abstract)

41. [13b–14b] Flexible articles are constructed by using folding frames on which images of men and other things, buildings, towers, etc., can be mounted at will to form a spectacle. The frames are made of bamboo, hemp-rope, and paper. There are self-illuminated figures and figures to be illuminated. Fire wheels, fountains, crackers, rockets, flower-moons, flying rats, etc., may also be mounted on the same frames. Fireproof materials are always procured by treating with alum solutions.

Fireproof Screens (Abstract)

42. [14b–15b] When three or four spectacles or displays are mounted and folded up into one package, the bottom spectacle must be separated from the upper one by means of a screen of fireproof paper in order to prevent them from burning together. After the display has been exhibited, the screen is dropped off automatically. If alum alone is not sufficient to make the paper fire-proof, *lu kan shih* 爐甘石 (zinc bloom, zinc carbonate), *shih chih fên* 石脂粉 (fuller's earth) or lime may also be used in combination with it.

Head Fuses (Abstract)

43. [15b–16a] If a fire show is lighted at the bottom, the fire goes upward slowly. The difficulty is reduced by lighting it at the top also, so that it takes fire all over. This is done by means of head fuse or top match.

Rigid Pieces (Abstract)

44. [16b–17a] A rigid piece is used when there is only a single spectacle which does not need to be folded up.

Changing Shows or Transformations (Abstract)

45. [17a–b] The appearance of one thing which will change into another in a show, is called a changing show or transformation. Examples are: a fish changing into a dragon, a copper coin changing into a butterfly, the two *hsien* (immortals) giving *tao* 道, the two dragons playing with the ocean (the latter two items have two things change into one), the flat peach, and the god of longevity, and others.

Multiple Pieces (Abstract)

46. [17b–18a] In fireworks displays two or more sets of articles are sometimes fired separately and at

the same time in adjacent scenes to make up one spectacle. They are called combinations.

Flying Pieces (Abstract)

47. [18a–b] *Liu hsing* 流星 (flying star, rocket), flying rat, flower-moon, etc. are the small flying pieces. In plays, for instance, the *hsien*-people (immortals) hailing the crane, the envoy *Hsiao* 蕭 riding on the phoenix's back, the golden lotus bursting out from the ground, the five old men going back to heaven, etc. are the flying articles of larger designs.

Water Fireworks (Abstract)

48. [19a] Powder is put in pig's intestines, paper swans, bamboo cylinders, etc. to make fireworks which are fired on the surface of water. Colored smokes and water-mice are fired under the water.

Moving Pieces for Banquets (Abstract)

49. [19a–b] Small articles such as jumping grasshoppers, wandering fish, running snakes, galloping deer, etc., all of these being small pieces about an inch in length, are fired after a banquet. It is supposed that their smoke facilitates recovery from over-indulgence.

Folding Frames (Abstract)

50. [19b–20a] Folding frames in the form of leaves are made of iron wires. They can be folded over for the mounting of fireworks.

Assembling the Display (Abstract)

51. [20a–b] Pieces are fastened onto the frame with bamboo fibers or paper-wrapped iron wires, but not with hemp rope, for the latter slips.

Connections (Abstract)

52. [20b–21b] There are internal connections and external connections. The internal ones use powder while the external ones use match.

TABOOS

53. [22a] Essentially, no precautions are needed in the use of *huo hsi* 火戲 (fire-plays, fireworks), but, because of their violent character and light producing ability, wherein they resemble the sunshine on all the devils, they are not to be treated carelessly. Although *ni yün* 尼褌 (woolen cloth) and *ching pu* 經布 (muslin) can stop the shooting of a candle, and iron shots and magnetic stones are able to control sulfur, these are the specific properties of the substances, but human actions also accomplish their effects.

54. The compounding must not be done in a family which is in mourning. It is especially prohibited in the house where a funeral has been held or where a man has died, for there the misfortune of accidental fire is certain to happen.[5] In case the mourning is for someone outside of the immediate family, and in case the family wishes to buy powder and must use it, a piece of red silk-cloth may be hung in the compounding room to release (the family) from the prohibition of using powder. In a house where fireworks are being made, one must not burn *ts'an sha* 蠶沙 (grass?) or bamboo leaves lest by this means the essence of the saltpeter is weakened.

55. During the packing of powder, if a drum is beaten to strike power into the powder, the fire-flowers will be brighter. However, during the compounding, the sound of a drum must not be heard lest the powder in consequence acquire the defect of bursting. The ashes on the charcoal must be removed before use. If [22b] a charcoal with adhering ashes is used, the resulting powder will usually be impeded. Probably the ashes are the ghosts of charcoal and the charcoal is afraid of them.

56. Women are not allowed to handle the powder. If the powder is packed by women, the crackers will change into fountains and vice versa. Smoking is forbidden in the powder room. The room should be kept quiet and neat, and noisy talk forbidden in order that the soul of the powder may be soothed. Care must be taken to prevent any changes in the powder. The testing of powder must not be carried out at any place near the powder house. The filling of the cylinders must not be done near any fire or smoke. The apparatus for handling the powder must be closed tightly, and the access of wind must be prevented. After long standing in the wind, the powder takes fire spontaneously. Artifices after being loaded with powder, must not be heated again (for drying), for there is danger that the powder may show its behavior spontaneously after long-continued warming. The tamping or pounding of the powder must be neither too heavy nor too light, and the amount of the powder may not freely be increased or decreased. The packing of powder by lamplight is not permissible. The opening of the powder container on a rainy day is not permissible. Those who hold established formulas will be limited by them; who understands elemental changes?

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[5] Fireworks, especially crackers, are used in China solely for celebrations or for the purpose of expressing joy, and are avoided in times of sadness. They are supposed to have the power of driving devils away.

Skill of Craftsmanship (Abstract)

57. [22b] The various operations, the fastening of the artifices, the connecting of the fuses, the preparation of the powder, the tamping in of the charges, etc., all require special tricks of manipulation.

The Spare Pole (Abstract)

58. [23b] A stick or pole is useful in case some of the hanging pieces misfire or burn improperly.

A NOTE ON READING THE TREATISE HUO HSI LÜEH

By *Yang Fu-chi* 楊復吉

[24a] An account of fireworks has rarely been published. The only available information appears in *Yüeh ling kuang i* 月令廣義 (The *Yüeh-ling* Expanded, by *Fêng Ying-ching:* 馮應京) and in *Wan shu chih* 宛署記 (Memoranda of *Wan-shu*), both of which were written in the *Ming* 明 dynasty. These contain only a few words (on fireworks), and are of little use. *Chao Hsüeh-min* 趙學敏 of *Ch'ien-t'ang* 錢塘, giving himself to relating in detail the formulas for manufacturing fireworks, has prepared a book. Although the subject is trifling, much energy and patience has gone into the collecting and assembling of materials. The work really occupies a place which has never before been filled. By no means should we laugh a bit at this composition as useless. *Yang Fu-chi* of *Chên-tsê* 震澤, in the late summer of the year *kuei-yu* 癸酉 (1753).

NOTES

1. *Chao's* description of the purification of saltpeter is so incomplete that one is tempted to infer that he had had no experience with the process. No effort appears to have been made to supply the deficiency of potassium in the crude material, or to replace the calcium which is commonly present, as is done in Europe by the use of wood ashes.

2. It is interesting to find that saltpeter, the oxidizing agent, is related in Chinese chemistry of the eighteenth century to the negative principle, *yin*, as oxygen in Europe was considered to be dephlogisticated air, and that sulfur in China was the embodiment of the positive principle, phlogiston, the essence of pure *yang*.

3. Unpurified saltpeter containing sea salt is more hygroscopic than the purified material. Impure saltpeter encourages charcoal (with which it is mixed) to take up moisture, and iron filings to rust.

4. The clarification by means of glue would work. White turnips boiled in the solution of impure saltpeter would absorb a certain amount of the dissolved salts, and conceivably might, as the text suggests, remove the chlorides faster than the nitrates—but we have no information on this point.

8. The process which is here described for the preparation of liquid sulfur might well yield a solution of ammonium polysulfide which would have several of the characteristic properties of sulfur. It would, for example, blacken the common metals including mercury, and would also convert mercury into cinnabar by suitable manipulation. The other reactions which are enumerated are not so evident, the purple color with magnetic stone and the disturbance with saltpeter, for ammonium polysulfide solution does not react with saltpeter. With pig fat it would emulsify to form a salve or ointment.

10. Charcoal is hygroscopic. *Chao* recommends that it be kept, as we would say, "in a desiccator over lime."

11. Charcoal which has taken up water makes the compositions which contain it unreliable in their performance.

12. The wet method of making black powder, particular sulfurless gunpowder, is at present in use in this country. The text apparently refers to sulfurless gunpowder. Particles of charcoal impregnated with camphor (snow-lantern-powder) would produce an interesting effect when used in gerbs or fountains.

13. The powder is mixed with lacquer and cast; the resulting mass is not affected by moisture, and is stable in its properties. No analogous method was in use in Europe.

14, 15. Powdered cast iron and steel dust were used in Europe at this time, and mixtures containing powdered cast iron were generally called Chinese fire. Lieutenant Robert Jones, contemporary with *Chao*, reports the following formulas.

"For a Brilliant Fire. Meal powder twelve pound, saltpeter one pound, brimstone four ounces, and steel dust one pound and a half.

"Chinese Fire. Saltpeter twelve ounces, meal powder two pound, brimstone one pound two ounces, and beat iron twelve ounces.

"For Gerbes. Meal powder six pound, and beat iron two pound one ounce and a half."[6]

The same author gives six compositions "for standing or fixed cases" (fountains) of which two contain steel dust. Needle steel (drillings from the manufacture of needles) are used in gerbs in this country at present.

[6] Jones, "Artificial Fire-Works, Improved to the Modern Practice, From the Minutest to the Highest Branches," etc., 2nd ed., London, 1766, pp. 43, 44.

Cutbush states that "D'Incarville, a missionary at Pekin, obtained the process for making Chinese fire; and observes, that the pulverized cast iron they employ is called *iron-sand*, of which they have six numbers or varieties.[7] . . .

"The Chinese have long been in possession of a method of rendering fire brilliant, and variegated in its colours. Cast-iron, reduced to a powder more or less fine, is called iron-sand, because it answers to the name given to it by the Chinese. They use old iron pots, which they pulverize, till the grains are not larger than radish seed; and these they separate into sizes or numbers, for particular purposes."[8]

Chao's text indicates a real understanding of the properties of powdered iron, and mentions several wise precautions to be exercised in its handling. The practice of wrapping the powder in paper and keeping in a desiccator over lime is a good one, but it does not guarantee the keeping qualities of the mixtures in which the iron is subsequently used. Cutbush however recommends a somewhat similar method of storage. "As the goodness of iron or steel dust, in fire-works, depends greatly on its being dry, and not oxidized or rusted; its preservation must be accordingly attended to. The usual preservative is to put it in a box, lined with oiled paper, and covered with the same, or in tin cannisters, with their mouths well closed.[9] . . .

"It should be observed, that rockets, into the composition of which, iron-filings and iron-sand enter, cannot be long preserved, owing to the change which the iron undergoes in consequence of moisture."[10]

On the subject of preserving steel and iron filings, Jones says—"It sometimes may happen, that fire-works may be required to be kept a long time, or sent abroad; neither of which could be done with brilliant fires, if made with filings unprepared; for this reason, that the saltpeter being of a damp nature, it causes the iron to rust, the consequence of which is, that when the works are fired, there will appear but very few brilliant sparks, but instead of them a number of red and drossy sparks, and besides, the charge will be so much weakened, that if this should happen to wheels, the fire will hardly be strong enough to force them round; but to prevent such accidents, prepare your filings after the following manner."[11]

He then describes the process of coating the filings with sulfur by stirring them up with melted brimstone. This method was commonly used in Europe as late as the first half of the nineteenth century, but it is more usual now to coat the filings with beeswax, paraffin, or linseed oil.

17. Different kinds of charcoal for quick and for slow match.

18. The match is kept dry by means of lime.

20. The trick of leaving the ends of the match unpiped, and thus of causing the match tube or pipe to fall away from the piece after the match has burned, is one which does not appear to have been used in Europe. The piped match burns almost instantaneously, but the portion of the match which is not enclosed within the tube burns slowly.

21. The use of alum for fireproofing was ancient and widespread. Archelaos, one of the generals of Mithradates in the war with Rome in 87 B. C. fireproofed a wooden tower by means of alum, and the wooden siege engines which the Romans used in the war of Constantine and the Persians in 296 A. D. were similarly treated.[12]

22. Many kinds of dyed paper are bleached by the sulfur which is used in the compositions, but the common pigments are generally not affected.

23, 24. The Chinese technique in the making of fountains is described. The conical shape of the interior of the container provides what amounts to the choke or constricted exit for the gases in European practice.

25. Orpiment and realgar, sulfides of arsenic which occur naturally as minerals, were used in European compositions at an early date. They are combustible and burn with a bright, white light. They are also volatile, and yield yellow smokes to the extent that they escape combustion. The intent of the statement that shreds of cotton give violet light is not clear. Verdigris does impart a greenish or bluish color to the flame, especially if chlorides are present; lead compounds tend to give a lilac color; but black *light* from pine soot is obviously impossible. It is probable that the word, light, applied to the effects of verdigris, vermilion, white lead, and pine soot, is in error and that the appearance, like a smoke puff, of a cloud of the finely powdered material, blown about by the force of the burning composition, is really intended.

26. The lapis lazuli, cinnabar, and calomel are evidently intended to be used in the state of fine powders to produce colored clouds of dust, and the

[7] James Cutbush, "A System of Pyrotechny, Comprehending the Theory and Practice," etc., Philadelphia, 1825, p. 202.

[8] *Ibid.*, p. 371.

[9] Cutbush, *op. cit.*, p. 202.

[10] *Ibid.*, pp. 371–372.

[11] Jones, *op. cit.*, p. 83.

[12] Partington, "Origins and Development of Applied Chemistry", London, New York, Toronto, 1935, p. 148.

metal foils, gold, silver, and tin, to be blown out in the same way as the colored powders to produce interesting visual effects. Pitch burns to produce soot or black smoke. Calomel is volatile and will produce a white smoke; it is used occasionally at present, particularly in blue lights, to supply chlorine which enhances the blue color which copper compounds give to the flame. Potassium nitrate (saltpeter) mixed with combustible materials gives a violet flame, sodium nitrate a yellow one.

29. The wet method of making black powder is described, and explanations given of the effects of dry roasting and of wet roasting with the admixture of other substances.

30. A copper compound to reduce the yellowness of the flame. If the powder is boiled with rosin oil (possibly turpentine), its flame will be smaller in size but more lasting in time.

31. There are certain incombustible substances which are useful in the pyrotechnic art for the production of various effects.

32. Rosin can "concentrate spreading light into spot light" by preventing an explosive expansion of the mixture in which it is incorporated.

33. Mice-powder and moon-lantern-powder are special powders for use in particular fireworks. The author makes practical observations which suggest that he has had an extensive experience with pyrotechnics; he mentions the effects of the saltpeter, of the sulfur, of the charcoal, of the iron sand, etc., and the fact that obstructions in the choke cause the piece to shake or to jump about.

34–37. The coated and composite grains evidently represent a technique of Chinese origin and indicate that certain of the effects of the fireworks are intended to be observed in the daytime. The burning grains of powder trace out their flight both by their flame and by their smoke. A compact mass or grain of burning composition, thrown out from a rocket, Roman candle, gerb, fountain, or flower pot, is called a *star* in our present practice. Composite stars are made in this country in such manner that the stars change color while they are burning or that the single stars burst into several stars of the same or of different colors. But daylight fireworks have not been popular, and we have not known of stars being coated with materials which produce colored smokes as is described in the Chinese text. The use of iron sand would produce an effect similar to that of penny sparklers or of electric spreader stars.

38. It is a good practical observation that the powder for crackers must be packed loosely but that the powder for fountains is pressed hard. The hard-pressed mixture burns from its surface; the flame from the burning cannot penetrate into its mass. If it were loosely packed, like granular gunpowder, the mixture would burn rapidly throughout its mass and an explosion would result. The tendency of mixtures containing iron sand to lose their uniformity is also correctly noted. These mixtures must be stirred constantly while they are being loaded and then pressed, tamped, or pounded so firmly into place that they can no longer separate.

39. The Chinese names for the various pieces of fireworks are no more bizarre and fantastic than those which are used in this country. Recent American catalogues list such pieces as "jeweled cascade," "devil among the tailors," "golden sunrise," "whistling pigeon," "wheel of fortune," "illuminated surprise," "yellowstone wonders," "fountain of youth," "jack in the box," "horn of plenty," "diamond necklace," "Hawaiian frolic," "dance of the fairies," and "messenger to Mars."

42. The fireproofing of paper with alum, or, if this is insufficient, by the use of an additional dusting with zinc carbonate, fuller's earth, or lime.

54. Sympathetic magic: the bad effects upon the powder of mourning, death, funerals, etc., but, if the mourning is for someone outside of the immediate family, then its effect may be counteracted by magical means.

55. Magical effects on the powder of the beating of a drum. Wood ashes mixed into the powder make it burn more slowly.

56. An intermingling here of magic with sound good sense: several sage precautions to be observed in the handling or powder are mentioned. The statement that the powder takes fire spontaneously after long standing in the wind appears to be in error, but may perhaps contain a certain element of truth. The several components of the powder, differing in density, would be more or less separated by the wind, and the blowing about and settling of the dust would introduce new hazards which might result in easy, if not actually spontaneous, ignition.